**Supplemental Materials**

# Associations between green space surrounding kindergartens and hyperactivity behaviors among Chinese preschool children

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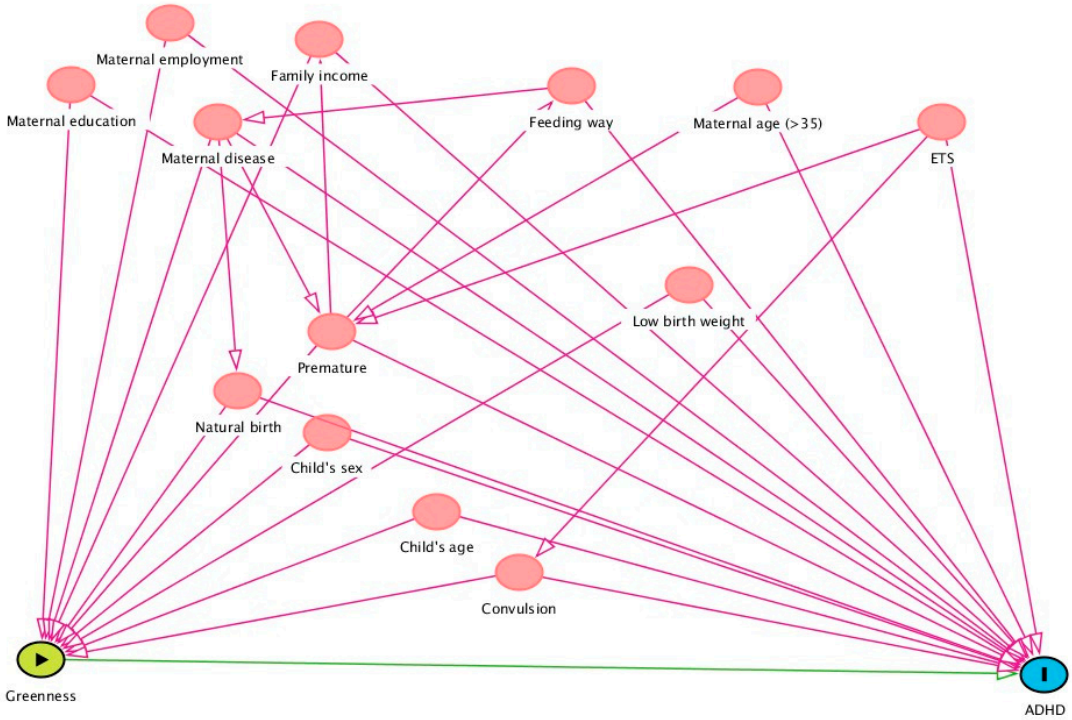


Figure S1 Directed acyclic graph for the association between greenness and hyperactivity behaviors.

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Table S1. Summary of epidemiological studies of associations between school-based greenness and ADHD/hyperactivity behaviors.

| Authors, year [reference] | Study-design | Country | Population | Green exposure metrics | Outcome metrics | Main findings |
|---|---|---|---|---|---|---|
| Malene Thygesen et al. 2020 | Cohort Study | Denmark | 814,689 children aged from 5years | Residential address (NDVI) | Based on ICD-10, and always assessed by child and adolescent psychiatrists. | Children who in early life lived in residences with low levels of green space (NDVI) surrounding the residential addresses had an increased risk of ADHD |
| Markevych et al. 2018 | Cohort Study | German | 66,823 children aged from 10 to 14 years | Residential address (NDVI) | Based on ICD-10-GM F90 diagnosis by a child/ adolescent psychiatrist, neuropediatrician or psychotherapist | An increase of 0.1-unit in NDVI decreased the relative risk of ADHD by a factor of 0.82 (95% confidence interval: 0.68-0.98) |
| Amoly et al., 2014 | Cross-sectional study | Barcelona | 2,111 school children (7-10 years of age) | Time spent playing in green spaces; residential surrounding greenness (NDVI) | ADHD evaluated by Strengths and Difficulties Questionnaires (SDQ) and Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (ADHD/DSM-IV) | There exist significant and inverse associations of ADHD symptoms scores with residential greenness, but not with residential proximity to major green space. School greenness was not associated with ADHD symptoms. |
| Geoffrey H Donovan et al. 2019 | Cohort Study | New Zealand | 49,923 children (<18 years) | Residential address (NDVI) | identify children with ADHD and to define covariates. ADHD was defined according to hospital diagnosis or pharmacy records (two or more prescriptions for ADHD drugs) | Greenness exposure in early life (prenatal to age 2 years) was not protective against ADHD, suggesting that exposure to the natural environment might moderate the symptoms of ADHD rather than preventing its development. |

| | | | | | | |
|---|---|---|---|---|---|---|
| Bo-Yi Yang et al. 2019 | cross-sectional study | China | 59,754 school children (2-17 years of age) | green spaces around schools and kindergartens | Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition) scales were used to measure ADHD symptoms (9 inattention symptoms and 9 hyperactivity-impulsivity symptoms). | There may be a beneficial association between school-based greenness and ADHD symptoms in Chinese children. |
| Yuchi W et al. 2022 | Cohort Study | Metro Vancouver, Canada | 28,797 school children | participants' residential postal codes | Diagnosis from hospital records, physician visits from MSP and prescriptions | Children living in greener neighborhoods had substantially lower risk of ADHD compared to lower greenspace exposure. |

Table S2. Characteristics of the study samples

| Characteristics | Subjects included in data analysis (n = 66,678) | Subjects excluded due to missing information (n =6,806) | P |
|---|---|---|---|
| Child sex | | | 0.15 |
| Boy | 36,425 (54.6) | 3,779 (55.5) | |
| Girl | 30,253 (45.4) | 3,027 (44.5) | |
| Child age (years) | 3.53 (0.36) | 3.49 (0.75) | <0.001 |
| Maternal age at childbirth | | | <0.001 |
| <= 35 years | 60,923 (91.4) | 6,315 (92.8) | |
| > 35 years | 5,755 (8.6) | 491 (7.2) | |
| Maternal education | | | <0.001 |
| Junior high school or lower | 10,251 (15.4) | 1,743 (26.3) | |
| High school | 36,774 (55.2) | 3,612 (54.4) | |
| College or higher | 19,653 (29.5) | 1,283 (19.3) | |
| Maternal employment | | | <0.001 |
| No | 29,670 (44.5) | 2,399 (37.2) | |
| Yes | 37,008 (55.5) | 4,052 (62.8) | |
| Maternal history of comorbidity | | | <0.001 |
| No | 62,000 (93.0) | 6,777 (99.6) | |
| Yes | 4,678 (7.0) | 29 (0.4) | |
| Family income (RMB/month) | | | <0.001 |
| <5000 | 5,831 (8.7) | 1,226 (19.6) | |
| 5001–10 000 | 14,492 (21.7) | 1,748 (28.0) | |
| 10 001–20 000 | 23,791 (35.7) | 1,914 (30.7) | |

| | | | |
|---|---|---|---|
| >20 000 | 22,564 (33.8) | 1,353 (21.7) | |
| Natural birth | | | <0.001 |
| No | 27,619 (41.4) | 3,068 (45.1) | |
| Yes | 39,059 (58.6) | 3,738 (54.9) | |
| Feeding patterns | | | <0.001 |
| Breast feeding | 28,952 (43.4) | 2,540 (37.9) | |
| Mixed feeding | 30,755 (46.1) | 3,312 (49.4) | |
| Artificial feeding | 6,971 (10.5) | 848 (12.7) | |
| Preterm Birth | | | 0.19 |
| No | 61,439 (92.1) | 5,964 (91.7) | |
| Yes | 5,239 (7.9) | 542 (8.3) | |
| Environmental tobacco smoke | | | <0.001 |
| No | 48,914 (73.4) | 4,283 (65.3) | |
| Yes | 17,764 (26.6) | 2,274 (34.7) | |
| Febrile convulsion | | | <0.001 |
| No | 58,464 (87.7) | 5,365 (83.2) | |
| Yes | 8,214 (12.3) | 1,083 (16.8) | |
| Low birth weight | | | <0.001 |
| No | 63,118 (94.7) | 5,188 (92.6) | |
| Yes | 3,560 (5.3) | 414 (7.4) | |

Note: There is no difference in the distribution between the sample and the excluded population.

Table S3: Summary of greenness indices and correlations between NDVI and EVI.

| Exposure Indices | Min | Max | P25 | P50 | P75 | NDVI-250m | NDVI-500m | NDVI-1000m | EVI-250m | EVI-500m | EVI-1000m |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $NDVI_{250m}$ | 0.16 | 0.67 | 0.24 | 0.28 | 0.33 | 1 | 0.97 | 0.87 | 0.95 | 0.92 | 0.84 |
| $NDVI_{500m}$ | 0.16 | 0.67 | 0.24 | 0.28 | 0.33 | | 1 | 0.94 | 0.92 | 0.96 | 0.91 |
| $NDVI_{1000m}$ | 0.19 | 0.64 | 0.24 | 0.28 | 0.32 | | | 1 | 0.81 | 0.89 | 0.97 |
| $EVI_{250m}$ | 0.10 | 0.41 | 0.14 | 0.17 | 0.20 | | | | 1 | 0.96 | 0.85 |
| $EVI_{500m}$ | 0.10 | 0.41 | 0.14 | 0.17 | 0.21 | | | | | 1 | 0.93 |
| $EVI_{1000m}$ | 0.12 | 0.39 | 0.14 | 0.17 | 0.20 | | | | | | 1 |

Table S4. Factors at each hierarchical level in regression analysis

| Hierarchical Level | Example of Hierarchical Level | Example Variables |
|---|---|---|
| Level-2 | School Level | NDVI, EVI |
| Level-1 | Student Level | Child sex, Child age, Maternal age at childbirth, Maternal education, Maternal employment, Maternal history of comorbidity, Family income, Natural birth, Feeding patterns, Preterm Birth, Environmental tobacco smoke, Febrile convulsion, Low birth weight, hyperactivity index |

Table S5. Odds ratios (OR) and 95% CI for the effect of baseline NDVI on hyperactivity behaviors in young children.

| Exposure | Case (N, %) | Crude model OR (95% CI) | P-value | Nagelkerke R square | Adjusted model [a] OR (95% CI) | P-value | Nagelkerke R square |
|---|---|---|---|---|---|---|---|
| NDVI 250 m | | | | | | | |
| Continuous (per IQR) | 1,183 (1.77) | 0.87 (0.79,0.95) | <0.05 | 0.04 | 0.91 (0.84,0.98) | <0.05 | 0.11 |
| Q1 | 327 (1.97) | | | | | | |
| Q2 | 324 (1.94) | 0.86 (0.71,1.04) | | | 1.01 (0.85,1.20) | | |
| Q3 | 262 (1.57) | 0.64 (0.52,0.79) | | | 0.78 (0.65,0.94) | | |
| Q4 | 270 (1.62) | 0.65 (0.52, 0.82) | | | 0.78 (0.65,0.94) | | |
| *p* for trend | | <0.05 | | | <0.05 | | |
| NDVI 500 m | | | | | | | |
| Continuous (per IQR) | 1,183 (1.77) | 0.86 (0.78,0.94) | <0.001 | 0.04 | 0.89 (0.83,0.96) | <0.001 | 0.11 |
| Q1 | 333 (2.02) | | | | | | |
| Q2 | 295 (1.76) | 0.74 (0.61,0.89) | | | 0.89 (0.74,1.06) | | |
| Q3 | 295 (1.77) | 0.69 (0.56,0.86) | | | 0.83 (0.69,1.00) | | |
| Q4 | 260 (1.56) | 0.60 (0.48,0.75) | | | 0.71 (0.58,0.86) | | |
| *p* for trend | | <0.05 | | | <0.05 | | |
| NDVI 1000 m | | | <0.001 | 0.04 | | <0.001 | 0.11 |
| Continuous (per IQR) | 1,183 (1.77) | 0.83 (0.75,0.91) | | | 0.87 (0.81,0.94) | | |

| | | | |
|---|---|---|---|
| Q1 | 324 (1.95) | | |
| Q2 | 317 (1.90) | 0.85 (0.7,1.03) | 0.96 (0.81,1.14) |
| Q3 | 272 (1.64) | 0.65 (0.51,0.81) | 0.81 (0.67,0.98) |
| Q4 | 270 (1.61) | 0.63 (0.5,0.80) | 0.71 (0.59,0.86) |
| *p* for trend | | <0.05 | <0.05 |

Table S6. β and 95% CI for the effect of baseline NDVI on hyperactivity index.

| Exposure | Case (N, %) | Crude model β (95% CI) | Adjusted model [a] β (95% CI) |
|---|---|---|---|
| NDVI 250 m | | | |
| Continuous (per IQR) | 1,183 (1.77) | -0.00237 (-0.00384, -0.00091) | -0.00205 (-0.00337, -0.00072) |
| Q1 | 327 (1.97) | | |
| Q2 | 324 (1.94) | -0.00257 (-0.00591,0.00076) | -0.00031 (-0.00342,0.00281) |
| Q3 | 262 (1.57) | -0.00759 (-0.01109, -0.00409) | -0.00502 (-0.00822, -0.00181) |
| Q4 | 270 (1.62) | -0.0073 (-0.01095, -0.00365) | -0.00539 (-0.00867, -0.00211) |
| *p* for trend | | 0.24 | <0.05 |
| NDVI 500 m | | | |
| Continuous (per IQR) | 1,183 (1.77) | -0.00256 (-0.00398, -0.00114) | -0.0023 (-0.00358, -0.00103) |
| Q1 | 333 (2.02) | | |
| Q2 | 295 (1.76) | -0.00548 (-0.00879, -0.00217) | -0.00279 (-0.00589,0.00031) |
| Q3 | 295 (1.77) | -0.00631 (-0.00986, -0.00277) | -0.0041 (-0.00731, -0.00088) |
| Q4 | 260 (1.56) | -0.00885 (-0.01254, -0.00515) | -0.00707 (-0.01037, -0.00378) |
| *p* for trend | | 0.23 | <0.05 |
| NDVI 1000 m | | | |

| | | | |
|---|---|---|---|
| Continuous (per IQR) | 1,183 (1.77) | -0.00312 (-0.00451,-0.00173) | -0.00276 (-0.00398,-0.00154) |
| Q1 | 324 (1.95) | | |
| Q2 | 317 (1.90) | -0.00268 (-0.00605,7e-04) | -0.00117 (-0.00429,0.00195) |
| Q3 | 272 (1.64) | -0.00752 (-0.01115, -0.00389) | -0.00477 (-0.00801, -0.00152) |
| Q4 | 270 (1.61) | -0.00808 (-0.01185, -0.0043) | -0.00711 (-0.01042, -0.0038) |
| *p* for trend | | 0.15 | <0.05 |

a: Adjusting for child's sex, age, highest level of maternal education, maternal employment, age at childbirth, history of comorbidity, family income monthly, natural birth, feeding patterns, preterm birth, febrile convulsion, low birth weight and ETS.

Table S7. Odds ratios (OR) and 95% CI for the effect of baseline EVI on hyperactivity behaviors.

| Exposure | Case (N, %) | Crude model OR (95% CI) | Adjusted model [a] OR (95% CI) |
|---|---|---|---|
| EVI 250 m | | | |
| Continuous (per IQR) | 1,183 (1.77) | 0.95 (0.87,1.04) | 0.90 (0.83,0.98) |
| Q1 | 283 (1.70) | | |
| Q2 | 317 (1.91) | 1.13 (0.94,1.37) | 1.07 (0.90,1.28) |
| Q3 | 303 (1.82) | 1.02 (0.83,1.25) | 0.99 (0.82,1.19) |
| Q4 | 280 (1.67) | 0.91 (0.74,1.12) | 0.80 (0.66,0.97) |
| *p* for trend | | 0.24 | <0.05 |
| EVI 500 m | | | |
| Continuous (per IQR) | 1,183 (1.77) | 0.93 (0.85,1.03) | 0.87 (0.80,0.95) |
| Q1 | 290 (1.74) | | |
| Q2 | 291 (1.75) | 0.96 (0.79,1.17) | 1.05 (0.88,1.25) |
| Q3 | 336 (2.01) | 1.07 (0.88,1.31) | 1.03 (0.86,1.23) |
| Q4 | 266 (1.59) | 0.84 (0.68,1.04) | 0.75 (0.63,0.91) |
| *p* for trend | | 0.23 | <0.05 |
| EVI 1000 m | | | |
| Continuous (per IQR) | 1,183 (1.77) | 0.91 (0.83,1.00) | 0.85 (0.78,0.92) |

| | | | |
|---|---|---|---|
| Q1 | 280 (1.70) | | |
| Q2 | 334 (1.98) | 1.09 (0.90,1.31) | 1.04 (0.87,1.25) |
| Q3 | 276 (1.66) | 0.86 (0.69,1.06) | 0.81 (0.67,0.99) |
| Q4 | 293 (1.76) | 0.91 (0.74,1.13) | 0.76 (0.62,0.92) |
| *p* for trend | | 0.15 | <0.05 |

a: Adjusting for child's sex, age, highest level of maternal education, maternal employment, age at childbirth, history of comorbidity, family income monthly, natural birth, feeding patterns, preterm birth, febrile convulsion, low birth weight and ETS.

Table S8. Odds ratios (OR) and 95% CI for the effect of baseline NDVI on hyperactivity behaviors additionally adjusted $NO_2$.

| Exposure | Case (N, %) | Adjusted model [a] OR (95% CI) |
|---|---|---|
| NDVI 250 m | | |
| Continuous (per IQR) | 1,183 (1.77) | 0.92 (0.85,0.99) |
| Q1 | 327 (1.97) | |
| Q2 | 324 (1.94) | 1.01 (0.85,1.20) |
| Q3 | 262 (1.57) | 0.79 (0.66,0.95) |
| Q4 | 270 (1.62) | 0.81 (0.67,0.97) |
| *p* for trend | | <0.05 |
| NDVI 500 m | | |
| Continuous (per IQR) | 1,183 (1.77) | 0.90 (0.84,0.97) |
| Q1 | 333 (2.02) | |
| Q2 | 295 (1.76) | 0.87 (0.73,1.04) |
| Q3 | 295 (1.77) | 0.86 (0.72,1.03) |
| Q4 | 260 (1.56) | 0.73 (0.60,0.88) |
| *p* for trend | | <0.05 |
| NDVI 1000 m | | |
| Continuous (per IQR) | 1,183 (1.77) | 0.88 (0.81,0.94) |

| | | |
|---|---|---|
| Q1 | 324 (1.95) | |
| Q2 | 317 (1.90) | 0.97 (0.82,1.15) |
| Q3 | 272 (1.64) | 0.83 (0.69,0.99) |
| Q4 | 270 (1.61) | 0.72 (0.60,0.87) |
| *p* for trend | | <0.05 |

a: Adjusting for child's sex, age, highest level of maternal education, maternal employment, age at childbirth, history of comorbidity, family income monthly, natural birth, feeding patterns, preterm birth, febrile convulsion, low birth weight, ETS and $NO_2$